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As I was preparing this talk, one of my favorite editors wrote that "As this country heads into the 1970's, it is in a state of such rapid and intricate change, that to understand your society you must think of it as a liquid in turbulent flow. You can't rely on solid organizational structures; they'll change. You can't locate any useful boundary between your own area of responsibility and the turbulence outside; the outside comes flooding in." This to me seems to set the theme for the discussion I am going to make today.

Actually our present direction in materials and construction quality controls was initiated in the late '50's, when many of the highway agencies initiated a final record and sampling program as an end point engineering audit of construction. The information obtained opened the eyes of both the contractors and engineers insofar as the effectiveness of method specifications which were the type then in vogue and in varying degrees, still are. Immediate results were that the engineers tended towards stricter enforcement of existing specifications, and the contractors responded by saying that most of the specifications handcuffed them by telling them how to do something rather than what was wanted. The engineer responded to this by trending towards end point specifications and so as to prove his point the contractor responded by pressure on the equipment industry to furnish equipment that would indeed have the accuracy required. This resulted in an increasing use of automated machinery, particularly for paving, bases and sub-bases. Such machinery is increasing in efficiency every day and now can easily spread and trim any of the various courses to tolerances as tight as 0.05.

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NEW TRENDS IN MATERIALS AND CONSTRUCTION QUALITY CONTROLS

By

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As I was preparing this talk, one of my favorite editors wrote that "As this country heads into the 1970's, it is in a state of such rapid and intricate change, that to understand your society you must think of it as a liquid in turbulent flow. You can't rely on solid organizational structures; they'll change. You can't locate any useful boundary between your own area of responsibility and the turbulence outside; the outside comes flooding in." This to me seems to set the theme for the discussion I am going to make today.

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responded to this by trending towards end point specifications and so as to prove his point the contractor responded by pressure on the equipment industry to furnish equipment that would indeed have the accuracy required. This resulted in an increasing use of automated machinery, particularly for paving, bases and sub-bases. Such machinery is increasing in efficiency every day and now can easily spread and trim any of the various courses to tolerances as tight as 0.05.

There are other developments in equipment such as plate and vibratory rolling, now in its infancy, but with great potential in the placement of materials. Automated batching plants with printouts are increasing in use throughout the nation. We here in California are still experimenting, but this practice undoubtedly is going to lead to much higher and better controlled production.

This effort has resulted in our highway product not only being turned out better than it ever has been, but also a great deal faster. So fast, as a matter of fact, that the engineer is finding it difficult to maintain his quality control at the same speed. It has been necessary, therefore, to start examining our entire quality assurance program. This was highlighted in 1964 during a trip of a team sponsored by the Bureau of Public Roads throughout the United States with the objective of initiating the use of statistical quality control in an overall program. Frankly, some of the statements made by this team scared the living daylights out of most construction engineers, primarily because this team was made up of statisticians who seemed to be saying the only way to do it was to take a lot more samples so as to be statistically correct in the assurance of your quality. Unfortunately with native materials the numbers of samples needed appeared to be completely impractical. Later these same people started to listen to, and understand, the engineer. We have now arrived at the stage where the engineer seems willing to accept an end point concept, but the average contractor is not yet quite prepared to accept the quality assurance program, which is a necessary part, as his responsibility. It is interesting that most materials suppliers are recognizing this trend and are already manned and equipped. Many of the larger contractors are staffing in this direction, and probably will continue in an accelerated manner with the smaller contractors relying on commercial laboratories for this service.

Most engineers have ideas about quality control and how it should be achieved, but few stop and ask themselves basic questions which will assure them of the quality that they wish. These basic questions are:

1. What do we want?
2. How do we order it?
3. How do we determine we got what we wanted?

In answer to the first question - most designs are developed by experience supplemented by research, so insofar as the completed project is concerned, we know what we want. Unfortunately, our studies of present recipe specifications indicate that they do not give us precisely what we want. The reason seems to be because they are based on a series of separate steps to obtain a final result. This means that any variations in the many steps might be accumulative and therefore result in an end product unlike that assumed in the original development studies. This problem leads to end point specifications as a clear manner to indicate our desires.

The second question, "How do we order it?" involves the writing of specifications and drawing plans. Plans are usually self explanatory although some field engineers think otherwise on occasion. The specifications, however, are written with words, and words are subject to interpretation - the contractor having his and the engineers having theirs. The same is true with specification limits for any test quality of a material. Our present specifications do not allow any leeway, they do not consider that there is a gray area. When we tell the contractor we want 30 to 50 percent passing the No. 30 sieve, are we really telling him what we want? We could say we want a material with 40 percent passing the No. 30 sieve, and allow him a plus or minus 10 percent tolerance. This immediately puts a different connotation on the specification, for now we have told the contractor what we want and how much tolerance we are going to give him. We no longer would say that if you make a material that averages 40 percent we will negotiate whether or not we will give you 29 percent.

It has been this need to be more specific in the specification area that is leading us to the use of statistical parameters in writing specifications. We need some sound criteria for the specifications given to the contractor so the contractor will know what kind of a risk he is running when he bids to meet this specification, and so the buyer will know the risk of accepting poor material and what the actual possibilities are that a contractor can meet the specification.

The third question, "How do we determine we got what we wanted?" raises the question of testing and how do we know our test is correct. In other words, it raises the question of precision and accuracy of test methods. This is an area that both ASTM and AASHO are currently exploring in great depth, and we are already starting to see better definitions.

A great deal is being accomplished throughout the country to try to achieve a better quality assurance program. In California for instance we are working on a number of fronts. I think most of you are aware that we have been working with statistical parameters to improve our specifications, that we have generally adopted a method of writing specifications for aggregate products, such as concrete, base, subbase, asphalt concrete, cement treated base, based on a running average measurement. In this scheme, the last five tests are averaged to determine the product quality. In addition to limits on the variability of this average we also have a wider limit allowing variation in individual tests. This is to compensate somewhat for the variability in sampling and also the variability in testing for individual samples. It is interesting to note that other agencies working in this field have arrived at similar systems. Some of these are the United Kingdom, Canada, the State of New York, West Virginia, Louisiana, and others. The running average seems to offer the only economical method of obtaining an average that can be used as a specification requirement for processed materials.

For unprocessed materials we find that the running average is not a good measure. Roadway excavation is an example. Here we use the area concept. This requires the taking of a specific number of tests and averaging. The acceptance or rejection of the entire area is based on this average as well as minimum requirements for the individual determinations. Such a system works only if the speed of the testing can be matched to the speed of construction, as we have done with nuclear testing.

However, where materials are fairly uniform and we are only interested in exceptional variations and where time is a large factor, the running average appears to be an excellent tool. Several of the counties have also explored this approach with some success. Basically, the running average is popular because it shows trends, and generally when a contractor sees a warning trend he will do something about it before problems develop. We should be well aware, all of us, that at today's production rates it is not economical for the contractor to be shut down for any reason whatsoever. It is more economical to produce materials that meet the specification than it is to fight the battle of start and stop which always arises with a borderline operation.

We are also working, along with other agencies, on the reproducibility of tests and trying to get more realistic values on reproducibility and precision. To do this requires a lot of long, hard, tedious laboratory work. For such values cannot be determined with a few tests and still be statistically correct.

The future will bring faster, bigger, and we hope more accurate, equipment, so we are trying to set up methods for measuring the performance of new equipment. How many samples should be taken? How extensive an investigation is needed? What is the standard deviation and how does this compare with other machines that have been tested? Having done this, the question is raised, does this improve the quality of the material, does it produce a more uniform material, and will more uniformity allow any savings, such as a reduction in cement content, lime content, asphalt content, etc.?

On the subject of uniformity, it might be well to note that other states are working on this problem. One state, Illinois, has written a trial set of specifications in which the contractor is penalized if he does not meet the uniformity requirements, but he is given a bonus if he exceeds them. An example of how this might affect a specific item could be in the uniformity of spreading and mixing lime for lime treatment. Those of you who have had this experience know lime spreaders can be notoriously inefficient and can do a very poor job of making a uniform spread. So in order to insure a minimum amount of lime, one must add at least one percent extra lime in order to achieve a minimum value. Perhaps if the contractor were offered an adequate bonus for uniform spreading, he would have an incentive to build or use only the best equipment available.

In earth work nuclear gages are proving to be one of the more useful new tools. We are currently studying the use of nuclear densities for determining compaction of asphalt concrete and exploring the test panel method, developed by Virginia, for controlling compaction. In this method the contractor lays about 150-300 feet of asphalt concrete at the specified thickness, compacts it any way he wishes and develops a specific roller pattern. The adequacy of his compaction is determined by a random sampling and testing of the strip. If he achieves 95 percent of laboratory compaction, he may then compact the rest of his project using the test panel density as 100 percent relative compaction. Whenever materials sources or rollers or equipment are changed, a new test panel is made and the test repeated. Under this system the contractor may use any roller or spreading method that he wishes as long as the final product is satisfactory.

While we are speaking of quality tests, we should keep in mind that many of the tests used in highway work are control tests and do not give an absolute measure of quality. For example, the gradation test which is basic to all aggregate type materials merely tells what sizes of material you are receiving. It does not tell the quality of the material with respect to its durability or its ability to perform the function in which the material is supposed to perform. It is always used in conjunction with other tests. For example, we know that good concrete may be achieved with several gradations, providing the proper cement and water ratio is used and that the aggregate is a durable aggregate that will have proper lasting qualities. Our specifications reflect this and we allow the contractor to select a job formula but he must stay within fairly narrow bands on this job formula, for if his gradation jumps around without adjusting the cement content or the water cement ratio, you may end up with finishing problems, with concrete that does not meet the required strength, or with porous concrete that does not fulfill the function for which it was intended. Now there is a tendency to place this quality control in the hands of the contractor with the buyer checking the end point such as by strength, density, texture, and surface durability tests and other needs. When the contractor accepts this responsibility, then he must apply statistical quality control to his production so as to be sure of meeting the end point requirements.

Other new controls are coming into usage or are being developed which will speed up inspection decisions - such things as sonic equipment to judge welds and perhaps measure thickness and some qualities of concrete structures, x-ray defraction equipment to determine chemical constituants of a multitude of products, automatic samplers, especially when used with automatic plants, will provide better and faster control. We have used load cells for many years in various testing processes; now the use of such equipment is being considered for checking batching scales so that rather than delay a plant's production for a complete day, such scales can be checked out in a very short period during off working hours. All of these new tools and procedures combined with a greater usage of end point specifications will enable the engineer to perform his task of control easier and faster, and more matched to the rapidity of modern day construction.

So far we have discussed quality assurance in its usual rather narrow sense in construction control, whereas actually a quality assurance program for the highway structure involves design, construction and maintenance. Coupled with design in this sense is also the preparation of specifications and with construction is coupled the testing to see if quality has been achieved. With maintenance we must include not only the cost of maintenance, but the evaluation of the product. We must actually measure to determine if the design has met its intended function. To make the quality assurance program work there must be continual cooperation between these three areas. There must be feedback to design from construction as to the adequacy of the specifications and plans for construction purposes. Maintenance must feed back information to both design and construction so that the quality of workmanship can be improved and design life attained at the lowest possible cost. While we may think the purpose of a new specification is to upgrade the quality of the product, the actual proof is whether or not it survives the time life period for which it was designed, under the real working conditions.